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Report on Strength and Deflection Tests of Various Materials Used as Guard Rail Posts- Part I

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Kuhlman, H.F. and V.M. Sayers

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Introduction

On numerous occasions, questions have arisen concerning the strength and deflection characteristics of the various materials and designs used or proposed for use as guard rail posts. In the past, test information has been meager and unreliable.

Therefore, on March 1, 1956, Mr. F.N. Hveem authorized a testing project (Laboratory Project Authorization No. 6070) to determine ultimate strength and load deflection curves of redwood, treated Douglas Fir, concrete cast in asbestos-cement pipe, split rolled-steel sections, and railroad rail and rolled WF beam specimens. Test data obtained for these types (direct cantilever loading) are submitted herewith, together with a discussion of the equipment, test specimens, and testing method used. This report is designated as Part I. Additional tests, which will include additional types of specimens and will perhaps involve application of stress parallel as well as perpendicular to the face of the post, are planned for the near future. These will be covered in a later report.

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DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

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REPORT
ON
STRENGTH AND DEFLECTION TESTS OF
VARIOUS MATERIALS USED AS GUARD RAIL POSTS

PART I

57-19

May 10, 1957

MATERIALS & RESEARCH
SAGACITAS · SCIENTIA · STVDIVM
DEPARTMENT

State of California
Department of Public Works
Division of Highways
Materials and Research Department

May 10, 1957

Laboratory Project
Authorization
84 - S - 6070

Mr. J. W. Trask
Assistant State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

REPORT

ON

STRENGTH AND DEFLECTION TESTS OF

VARIOUS MATERIALS USED AS GUARD RAIL POSTS

PART I

Study made by . . . . Structural Materials Section
Under general direction of . . . . J. L. Beaton
Work supervised by . . . . H. F. Kuhlman
Report prepared by . . . . H. F. Kuhlman and V. M. Sayers

Very truly yours,

F. N. Hveem
Materials and Research Engineer

HFK/VMS:mw
cc: RHWilson
FWPanhorst
JALegarra

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INTRODUCTION

On numerous occasions, questions have arisen concerning the strength and deflection characteristics of the various materials and designs used or proposed for use as guard rail posts. In the past, test information has been meager and unreliable.

Therefore, on March 1, 1956, Mr. F. N. Hveem authorized a testing project (Laboratory Project Authorization No. 6070) to determine ultimate strength and load deflection curves of redwood, treated Douglas Fir, concrete cast in asbestos-cement pipe, split rolled-steel sections, and railroad rail and rolled WF beam specimens. Test data obtained for these types (direct cantilever loading) are submitted herewith, together with a discussion of the equipment, test specimens, and testing method used. This report is designated as Part I. Additional tests, which will include additional types of specimens and will perhaps involve application of stress parallel as well as perpendicular to the face of the post, are planned for the near future. These will be covered in a later report.

SUMMARY

The object of the testing program was to obtain comparative ultimate strength and deflection test data on the various materials. The designs and dimensions of the specimens used were equivalent to those in use, or proposed for use, as posts so as to obtain a comparison between typical post sections rather than between equal areas of the materials.

The materials and sections used included:

8" x 8" Redwood and Treated Douglas Fir Timber Posts

Concrete cast in 7" and 8" Asbestos-Cement Pipe (with two different methods of reinforcement)

Rolled steel 10" - H.P. - 43# section split diagonally through the web

6" WF - 15.5# steel beam

60 lb. used railroad rail.

Additional details of the specimens are described under "Test Specimens".

The concrete sections, poured in asbestos-cement pipe forms, had been suggested as an inexpensive type of post for guard rail. This type was therefore included in the tests for comparative evaluation.

The specimens were subjected to static cantilever loading. The unsupported length of the cantilever specimen was equivalent to the distance a post normally extends above the ground. At the beginning of the tests, the primary loading was transmitted to the specimen through the standard spring bracket bolted to the specimen. Use of the bracket was discontinued when it was found that it had little or no effect on the end results when the load was applied normal to the face of the post. Timber and concrete posts were tested to complete failure. Tests on steel posts were considered complete when "permanent set" had developed. Equipment and testing are described in greater detail under "Testing Details".

The test results are tabulated and graphed in Figures 9 through 14 of the Appendix.

This project was intended primarily to provide reference data for designers and specification writers of the Division of Highways rather than to furnish specific recommendations.

The test results are in general self-explanatory.

In evaluating the results, it should be borne in mind that the tests involved slowly applied loads and that in all probability there would be some difference if the loads were applied rapidly in the form of sharp impact or collision. Such loads are very difficult to simulate in any method other than by setting up a full scale test with typical vehicles. The shock absorbing qualities and deceleration effects of the average automobile body and frame are substantial and have far greater effects in reducing impact than can be expected from the rather light spring mounted bracket currently being used on our guard rail installations. Also, it must be emphasized that the strengths of the posts were measured under direct bending forces and do not necessarily reflect the ability of the various types of posts to withstand the twisting action which is developed virtually every time that a guard rail is struck. It is obvious, of course, that a steel beam guard rail distributes the force of collision among a number of posts. Such collisions involve a pulling action on the beam and a consequent twisting or "sideways" effect on every spring mounting of the type now being used.

A review of the tabulation of results (Figure 10) and of the composite deflection graph (Figure 14) shows the following:

1. For all the concrete posts, the total stress at failure was very low in comparison with the other post sections. The highest values for the concrete were obtained with the mesh-reinforced concrete in the 8" pipe, but the variation among the three concrete designs tested was not very great. The concrete

poured in 7" pipe and reinforced with #4 bar showed comparatively high deflections in addition to the lowest ultimate value of the series. It would appear that the concrete posts would have to be made in larger sections and have considerably more reinforcing in order to be structurally comparable to the other types. Any economic advantage would be correspondingly reduced.

2. The ultimate total stress for the treated Douglas fir is about the same as that for the 6" WF-15.5# beam. The redwood strength was lower but still considerably more than that of the concrete and split-beam sections.

3. The split H-beam showed comparatively low ultimate strength and high deflections.

4. The tests indicated the railroad rail to be structurally comparable to the standard timber and WF beam sections.

TEST SPECIMENS

The post sections were not specially prepared for testing. They were of the same dimensions and in the same condition as if delivered to the jobsite for installation.

The redwood posts were 8" x 8" x 4'8", dense select structural grade S4S, per Standard Specifications. The Douglas fir specimens were also typical of Standard Specification post material. They were 8" x 8" x 4'8", construction grade S4S, full cell pressure treated.

The split steel beam specimen was fabricated by splitting a 10" - HP - 43# section diagonally through the web, thereby making two posts from a 4'8" length of beam. The second type of steel post was a standard 6" - WF - 15.5# beam. The third type of steel post specimen was a section of 60 lb. used railroad rail.

The concrete posts were made in line with a proposal of the Johns-Manville Company by filling asbestos-cement pipe forms with concrete. One set was reinforced through the center with a standard half-inch reinforcing bar. The asbestos-cement pipe was 7" air vent style.

The second and third sets had cages made of welded wire fabric, fabricated from 6 gage cold-drawn wire spaced at 4" x 6" centers with the cages placed approximately ½" under the surface. The asbestos-cement form in each case was standard asbestos-cement pipe, (with a greater wall thickness than the air vent type). Seven-inch diameter pipe was used in one set and eight-inch in the other.

The concrete for all these specimens was Class A 6 sack, with 1-inch maximum size aggregate and approximately $2\frac{1}{2}$ inch slump, and was cured 28 days in open air.

The specimens were numbered for identification. The numbering key appears as Figure 9 of the Appendix.

TESTING DETAILS

Figures 1 and 2 and 8 show the position of the specimen in the Universal testing machine and the manner in which the stress was applied. The load was applied at a constant rate and deflection readings were taken at various increments up to failure, using the deflection indicating apparatus shown in Figures 1 and 8.

The failure of the timber and concrete specimens was instantaneous in all cases. Testing of the steel specimens was considered complete when a definite permanent set was obtained.

Figures 1 through 7 of the Appendix show various phases of the testing.

Figure 8 is a diagram of the apparatus and position of the posts. Figure 9 shows the numbering system used to identify each type of specimen.

Figures 10 through 14 are tabulations and graphs showing the results of the tests. Figure 15 is a comparative tabulation of costs and other data on the posts tested in this first phase of the program.

DISCUSSION AND CONCLUSIONS

The testing was limited to static cantilever loading as described. However, it is believed the test results provide a useful structural strength comparison of the various typical post sections tested, for reference in design and specification writing, as well as for general information.

The results, as tabulated and graphed in Figures 9 through 14 are in general self-explanatory.

Some general conclusions indicated by the test results are as follows:

1. The concrete post cast in asbestos-cement pipe, as suggested by pipe manufacturers, is not structurally comparable (at least for the design, dimensions, and reinforcing used for the tests) with the standard timber and steel post sections now in use. This is also true of the split H-beam sections.

2. The standard treated Douglas fir posts are much stronger than the redwood and compared favorably, under the conditions of the test, with the steel rail and H-beam sections.

3. As would be expected, the redwood post showed a lower ultimate strength than the Douglas fir, 6" - WF - 15.5# beam, and steel rail sections, but nevertheless appears to be structurally superior to the concrete and split beam sections, by a substantial margin.

4. These strength relationships do not necessarily reflect the behavior under sudden blows or shock. However, there is no reason to expect that the relationship for the H-beam or timber posts would be much affected. There might, however, be some question about rail steel, and it is virtually certain that concrete would be more adversely affected. A more exact evaluation, however, could only be obtained by tests on a full scale installation.

5. The data do not show the relative ability of these posts to withstand torsional strains or lateral pulls on the bolts which might tend to shear the bolts or split the posts.

In addition to the relationships indicated by the foregoing test series, other considerations must be borne in mind in any over-all evaluation of guard rail posts.

(a) Treated Douglas fir posts are not only stronger but undoubtedly resist decay much better than Redwood under all conditions.

(b) Redwood posts often have a better surface finish and are reportedly preferred by maintenance foremen because of ease in painting.

(c) Metal and concrete posts would be free from deterioration in the ground and would be permanently fireproof.

(d) The cylindrical concrete posts enclosed in an asbestos cement tube would present a smooth, uniform appearance and would be fireproof and free from decay and should require no painting or other maintenance. If broken, however, they would have little salvage value.

As a final word of caution, it must be recognized that the limiting factor in most present guard rail installations is the resistance of the ground in which the post is imbedded. In other words, the posts are usually knocked out and dislodged before they are broken and in most cases the strength of timber posts exceeds the ability of the ground to hold the posts in place.

APPENDIX

Photographs (Figures 1 through 7):

Other Exhibits:

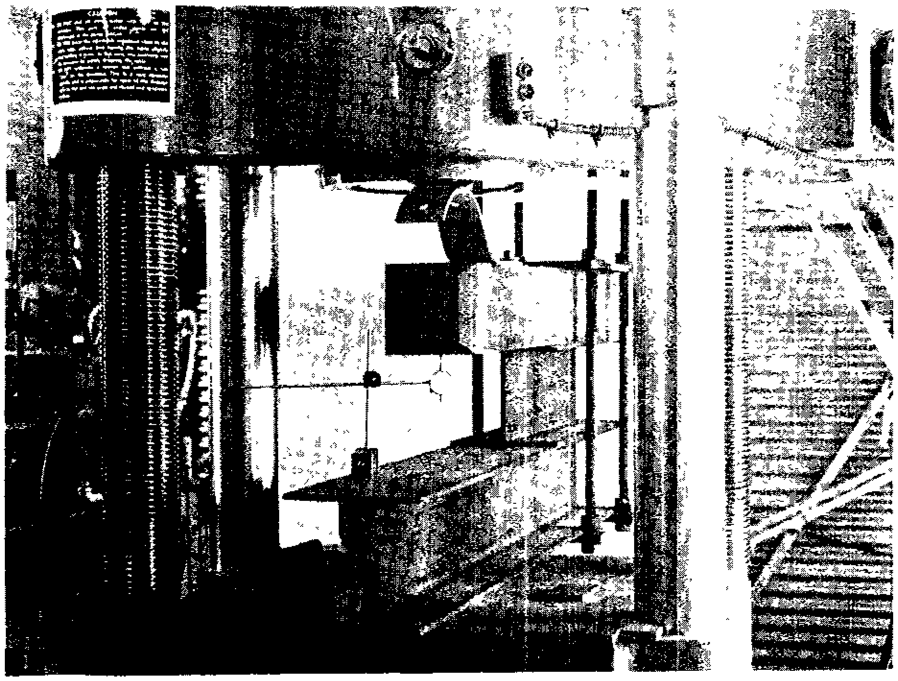


Figure 1

Redwood post in

place for testing.

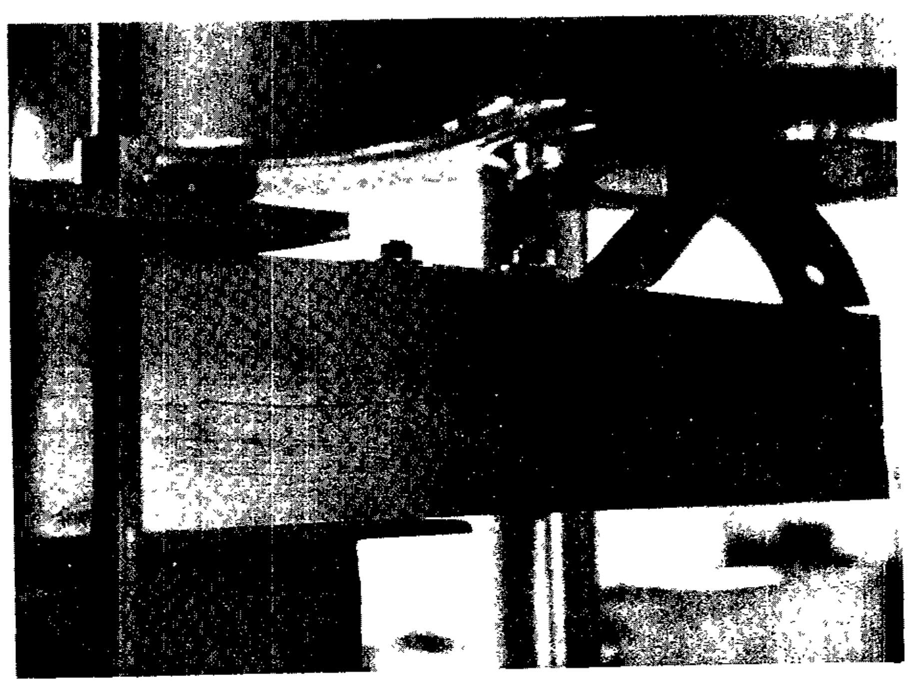


Figure 2

Typical failure of

timber post.

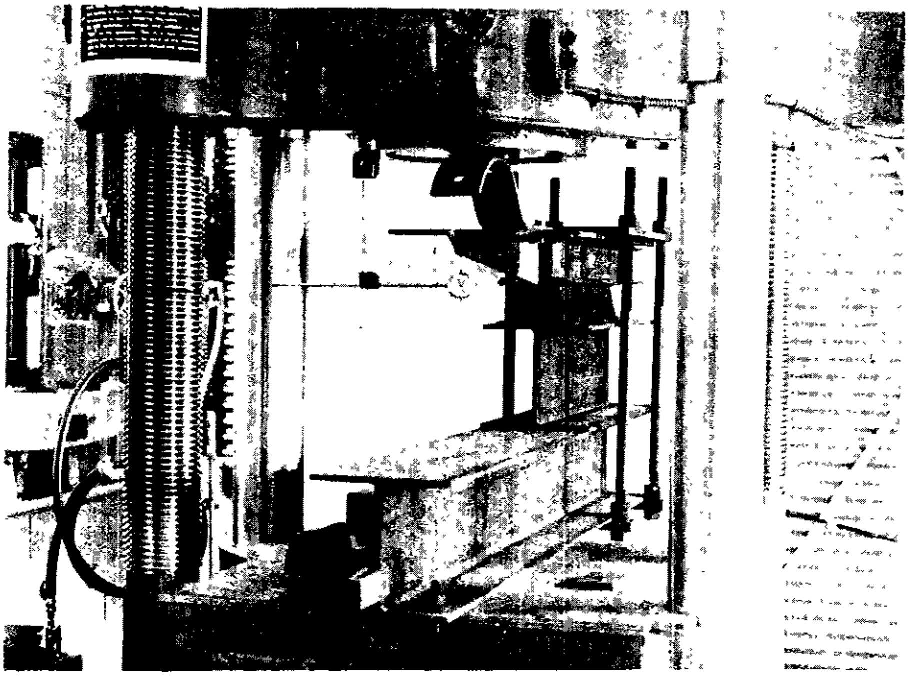
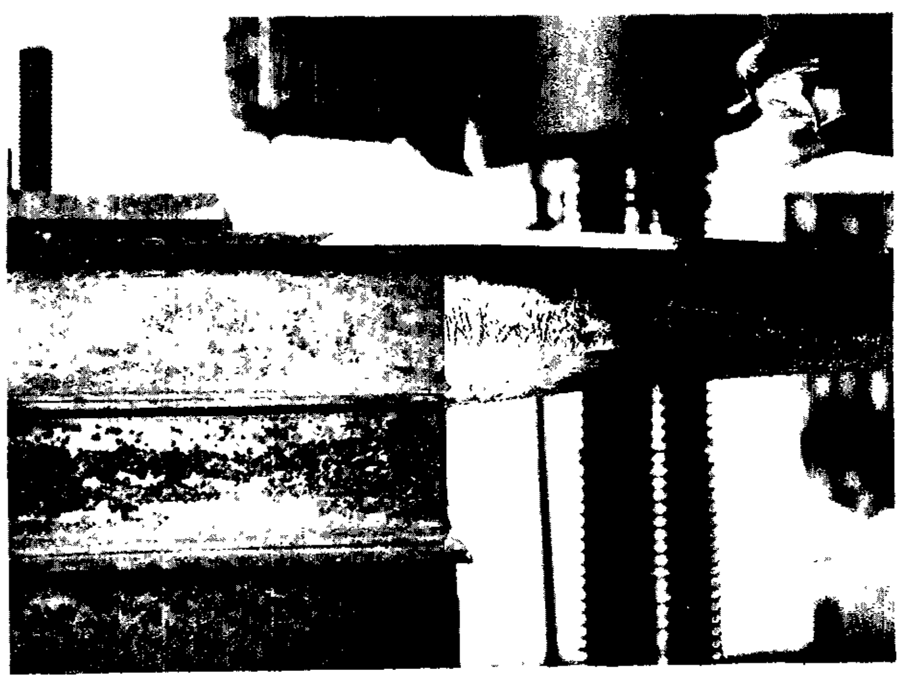


Figure 3
Split steel post in place for testing.

Figure 4
Shows stress lines developing in web of steel post during testing.



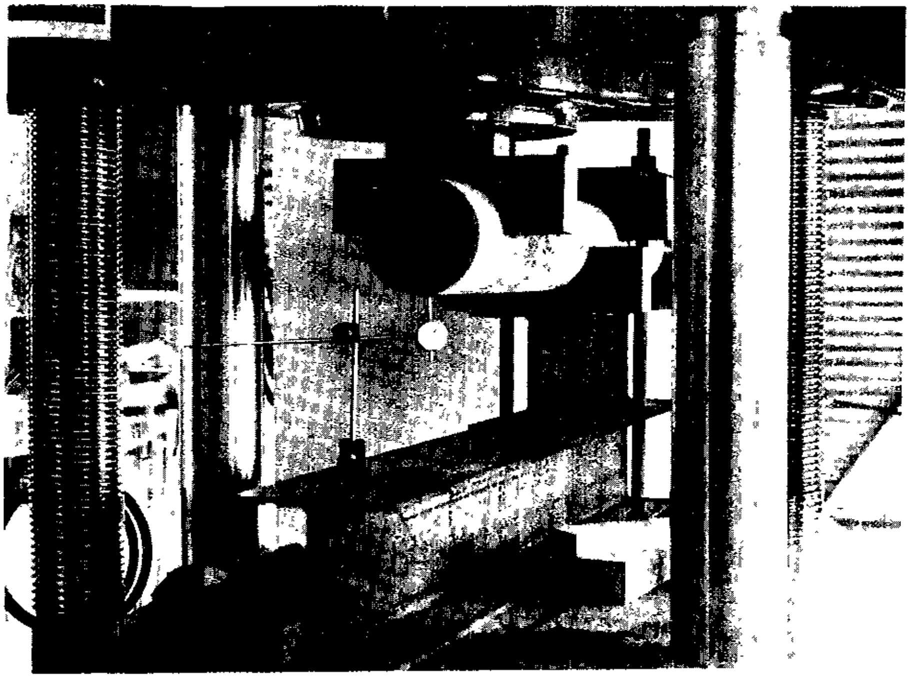


Figure 5
Concrete post in place
for testing.

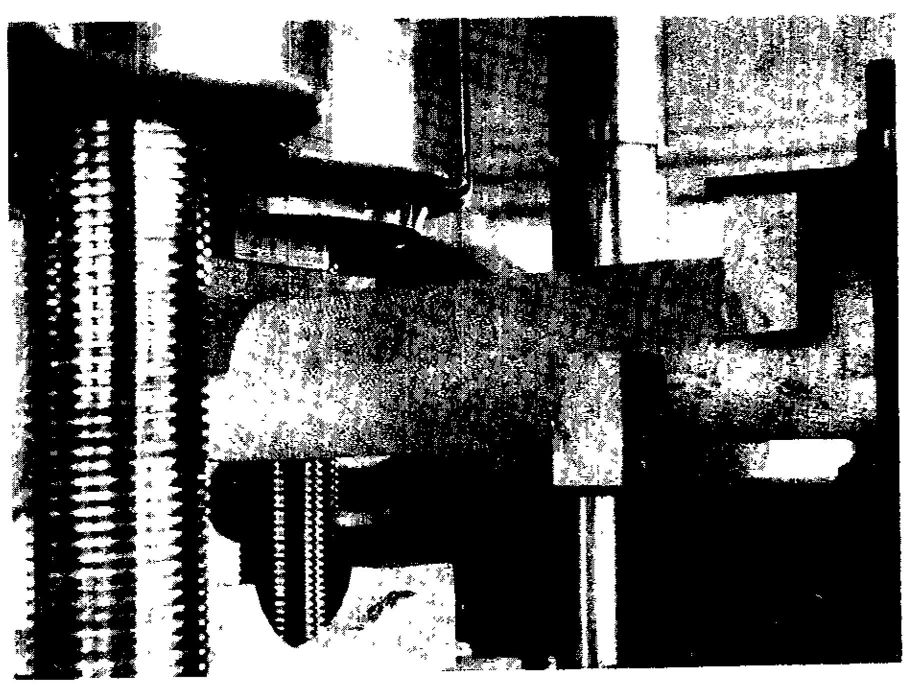


Figure 6
Typical failure in
concrete posts.

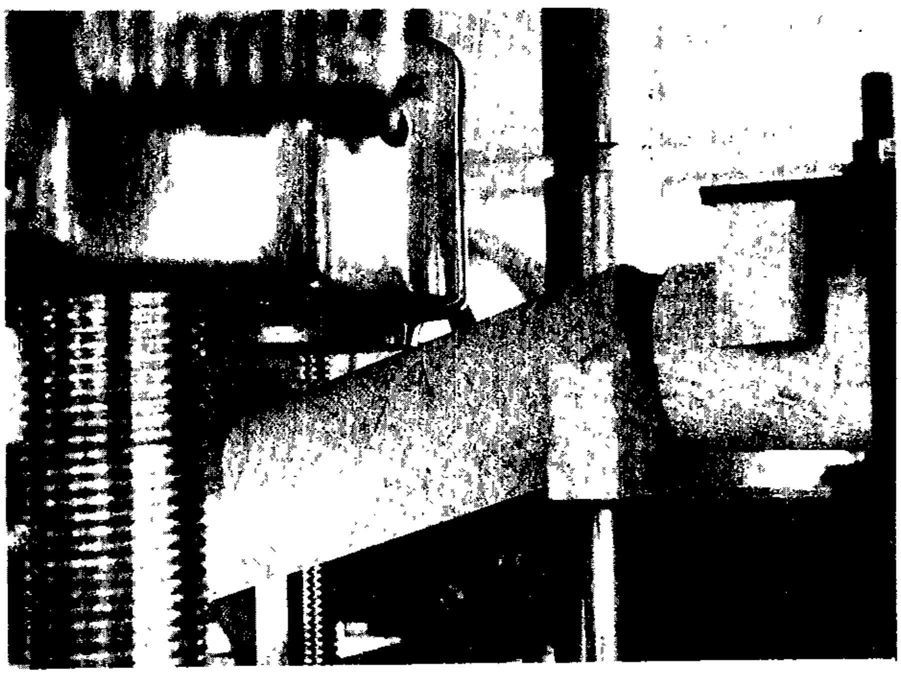
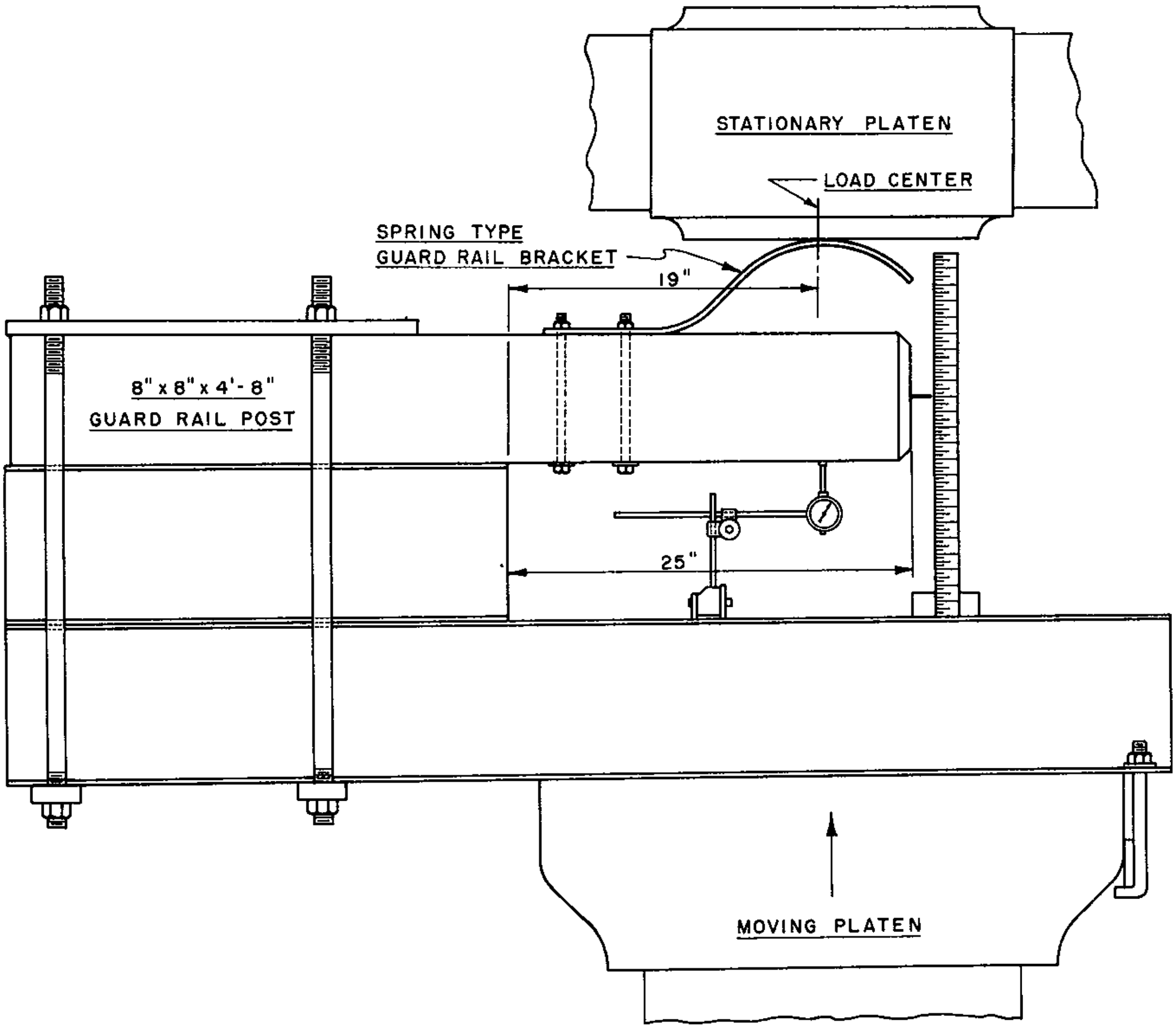


Figure 7

Complete failure of concrete

posts.



PRIMARY LOADING WITH GUARD RAIL BRACKET IN PLACE

(Ultimate Loading - Guard Rail Bracket removed and point load applied at load center.)

SCHEMATIC DIAGRAM OF CANTILEVER LOADING ON GUARD RAIL POSTS

IDENTIFICATION OF SPECIMENS

Specimen No.	
1, 2, 3	Redwood
4, 5	Split H-Section
7, 8, 9	7" asbestos-cement pipe with 4# reinforcing bar
10, 11, 12	Treated Douglas fir
13, 13-A	Railroad rail
14, 14-A	6" WF-15.5 lb. Section
15, 16, 17	7" asbestos-cement pipe with mesh cage
18, 19, 20	8" asbestos-cement pipe with mesh cage

Figure 10

TABULATION OF RESULTS

GUARD RAIL POST TEST

Load Lbs. — Post Number - Deflection in inches

Load Lbs.	1	2	3	4	5	7	8	9	10	11	12
500	0.03	0.00	0.03	0.07	0.04	0.07	0.04	0.03	0.05	0.03	0.03
1,000	.06	.03	.07	.12	.08	.12	.07	.05	.10	.07	.07
1,500	.08	.09	.09	.19	.13	.17	.15	.08	.15	.11	.09
2,000	.11	.11	.12	.23	.15	.22	.19	.12	.20	.14	.12
2,500	.15	.14	.15	.27	.20			.17	.23	.17	.14
3,000	.18	.16	.18	.31	.22				.25	.20	.18
3,500	.23	.18	.20	.35	.27				.28	.22	.20
4,000	.26	.21	.22	.39	.31				.30	.24	.22
4,500	.31	.24	.25	.42	.34				.33	.26	.24
5,000	.34	.26	.28	.43	.36				.35	.28	.26
5,500	.38	.28	.30	.47	.40				.38	.30	.29
6,000	.43	.31	.32	.51	.44				.40	.32	.32
6,500	.48	.34	.35	.55	.48				.42	.34	.35
7,000	.51	.37	.37	.58	.51				.44	.36	.37
7,500	.56	.39	.39	*.61	.56				.46	.38	.39
8,000	.60	.41	.42	.70	*.63				.48	.40	.42
8,500	.66	.44	.45	**.93	.83				.50	.42	.44
9,000		.48	.48		**1.25				.53	.44	.46
9,500		.50	.51		1.63				.55	.46	.49
10,000		.51	.55		1.99				.58	.48	.52
10,500		.56	.57						.60	.50	.55
11,000		.59	.60						.63	.52	.57
11,500		.62	.63						.65	.55	.60
12,000		.64	.66						.66	.57	.65
13,000		.71	.72						.71	.62	.72
14,000		.81	.78						.75	.66	.77
15,000			.88						.80	.72	.85
16,000			.95						.85	.78	.92
17,000			1.03						.90	.84	1.02
18,000			1.15						.95	.92	1.15
19,000									1.02	1.00	1.22
20,000									1.10	1.10	1.35
21,000									1.12		1.55
22,000									1.20		1.80
23,000									1.30	1.40	
24,000									1.37		
25,000									1.48		
26,000									1.60	2.40	
Failure	8,890	14,520	18,000	8,500	10,000	2,100	2,440	2,640	26,400	26,000	22,000
0 Load Set	0.28	0.24	0.36	1.36		1.05	1.31		0.20	0.50	0.25

* Initial Yield Point

** Yield Point of Entire Section

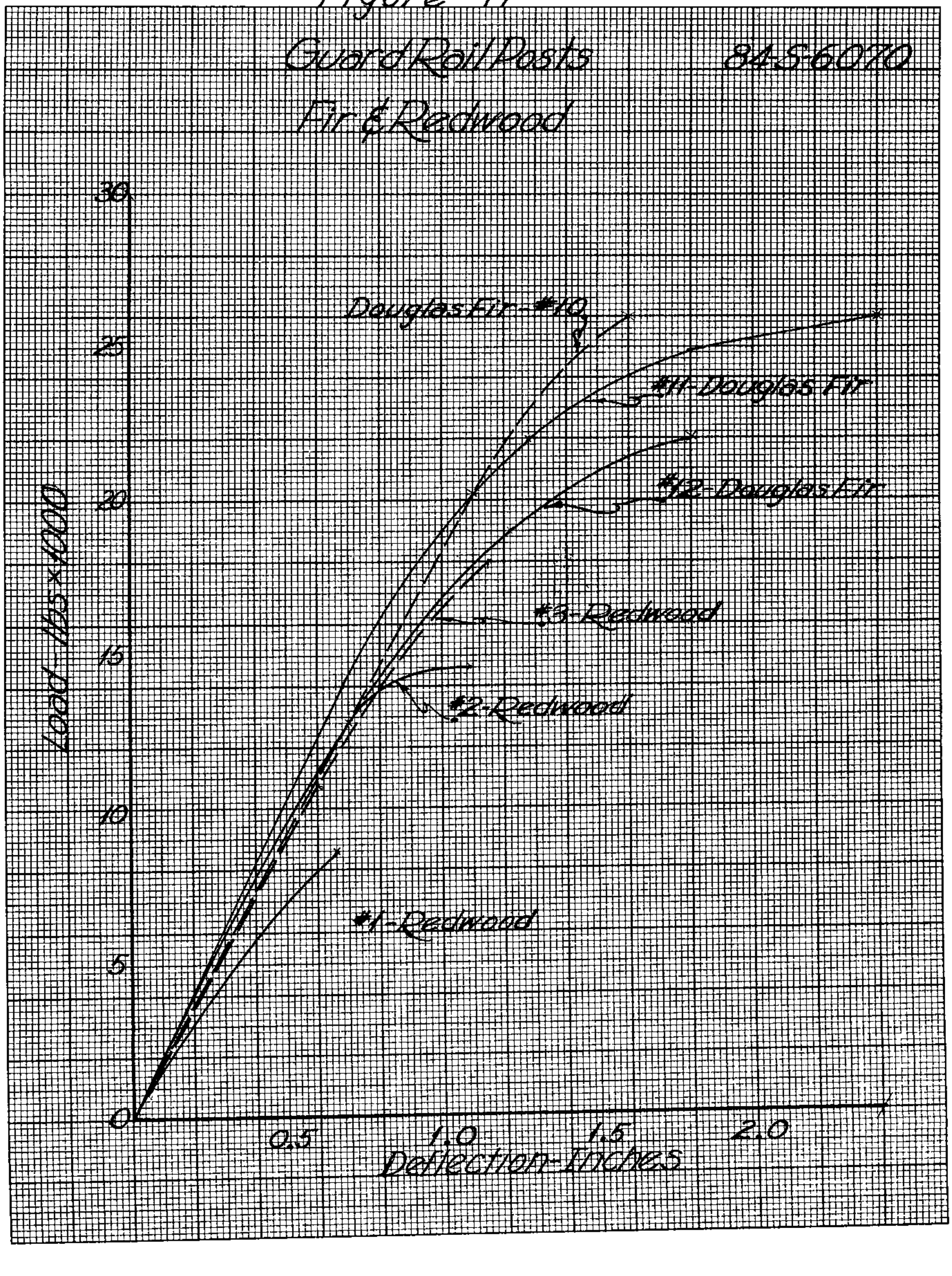
Post Number - Deflection in Inches

Load Lbs.	13	13-A	14	14-A	15	16	17	18	19	20
500	0.02	0.02	0.03	0.04	0.05	0.04	0.04	0.04	0.03	0.03
1,000	.04	.04	.05	.07	.07	.06	.06	.07	.05	.05
1,500	.06	.05	.08	.09	.09	.09	.09	.11	.08	.08
2,000	.08	.06	.11	.11	.12	.12	.11	.14	.10	.10
2,500	.10	.08	.12	.14	.14	.16	.14	.17	.13	.13
3,000	.12	.09	.14	.17	.17	.19		.20	.16	.15
3,500	.13	.10	.16	.19	.21			.24	.19	.18
4,000	.14	.11	.17	.20	.23			.28	.20	.20
4,500	.15	.12	.18	.22				.33	.23	.23
5,000	.16	.12	.20	.24				.37	.25	.26
5,500	.17	.13	.22	.26						
6,000	.18	.13	.23	.28						
6,500	.18	.14	.25	.29						
7,000	.19	.17	.26	.30						
7,500	.19	.18	.27	.31						
8,000	.20	.19	.29	.32						
8,500	.21	.20	.31							
9,000	.22	.21	.32	.34						
9,500	.23	.22	.34							
10,000	.24	.23	.35	.38						
10,500	.25	.24	.37							
11,000	.26	.26	.39	.41						
11,500	.27	.27	.41							
12,000	.28	.28	.42	.45						
13,000	.30	.30	.45	.48						
14,000	.31	*.32	.49	.50						
15,000	.32	.33	.52	.53						
16,000	.35	.34	.56	.56						
17,000	*.37	.37	.61	.59						
18,000		.39	.64	.62						
19,000		.42	.69	.66						
20,000		.44	.73	.69						
21,000		.47	.78	.72						
22,000		.52	.85							
23,000		.58		.80						
24,000		**.68	1.05							
25,000			*1.20	*.95						
26,000										
27,000				1.20						
Failure	17,000	24,000	25,000	27,000	4,000	3,000	2,800	5,200	5,800	5,200
0 Load Set	0.05	0.45	0.33	0.35	0.22	0.06	0.09	0.35	0.25	0.28

* Initial Yield Point

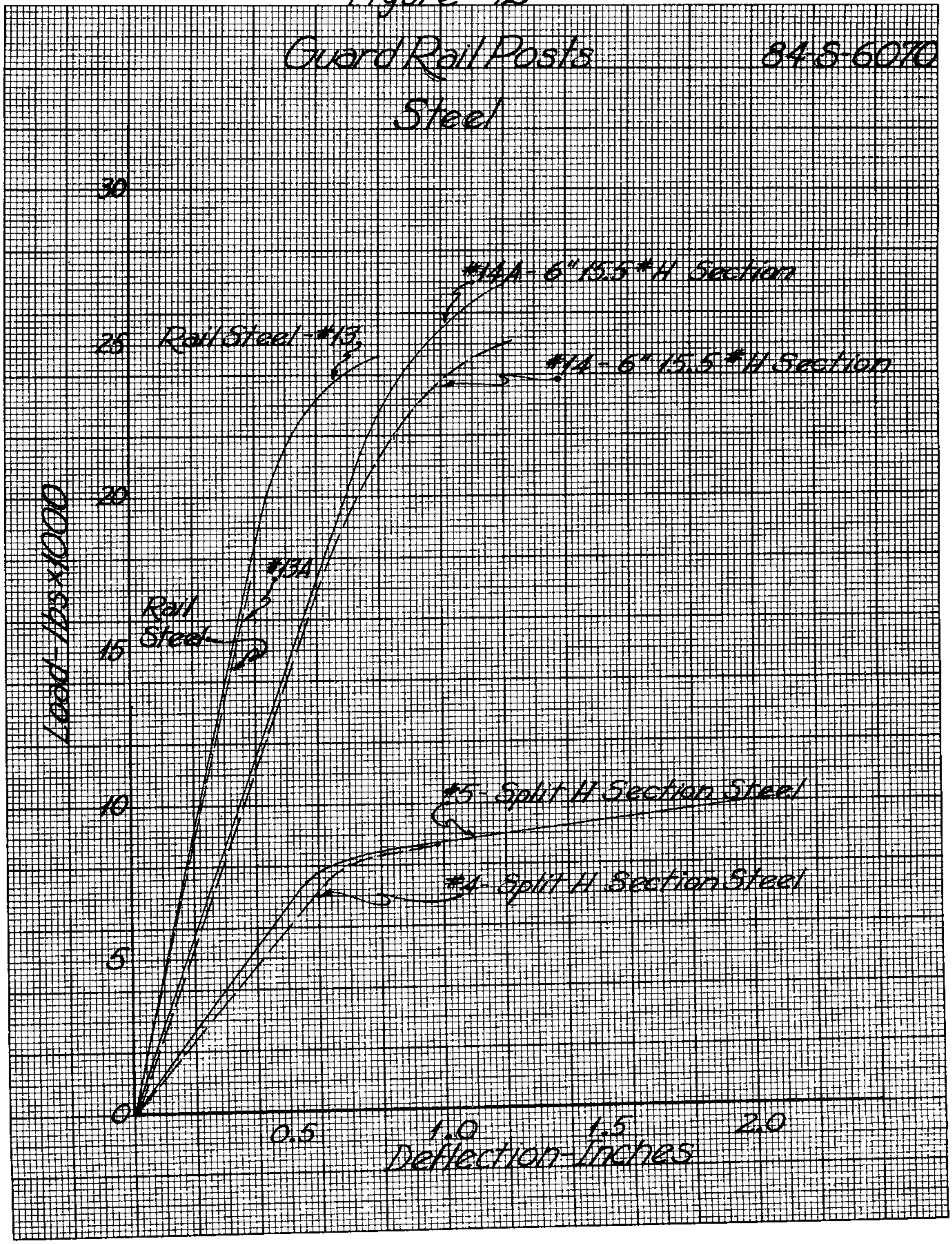
** Yield Point of Entire Section

Figure #11



Guard Rail Posts
84-S-6070
Fir & Redwood
Douglas Fir-#10
#11-Douglas Fir
#12-Douglas Fir
#3-Redwood
#2-Redwood
#1-Redwood
Load-lbs×1000
30
25
20
15
10
5
0
0.5
1.0
1.5
2.0
Deflection-Inches

Figure #12



Guard Rail Posts
84-S-6070
Steel
30
25
20
15
10
5
0
0.5
1.0
1.5
2.0
Load-lbs x 1000
Deflection-Inches
#14A-6" 15.5# H Section
Rail Steel-#13
#14-6" 15.5# H Section
#13A
Rail Steel
#5-Split H Section Steel
#4-Split H Section Steel

Figure #13

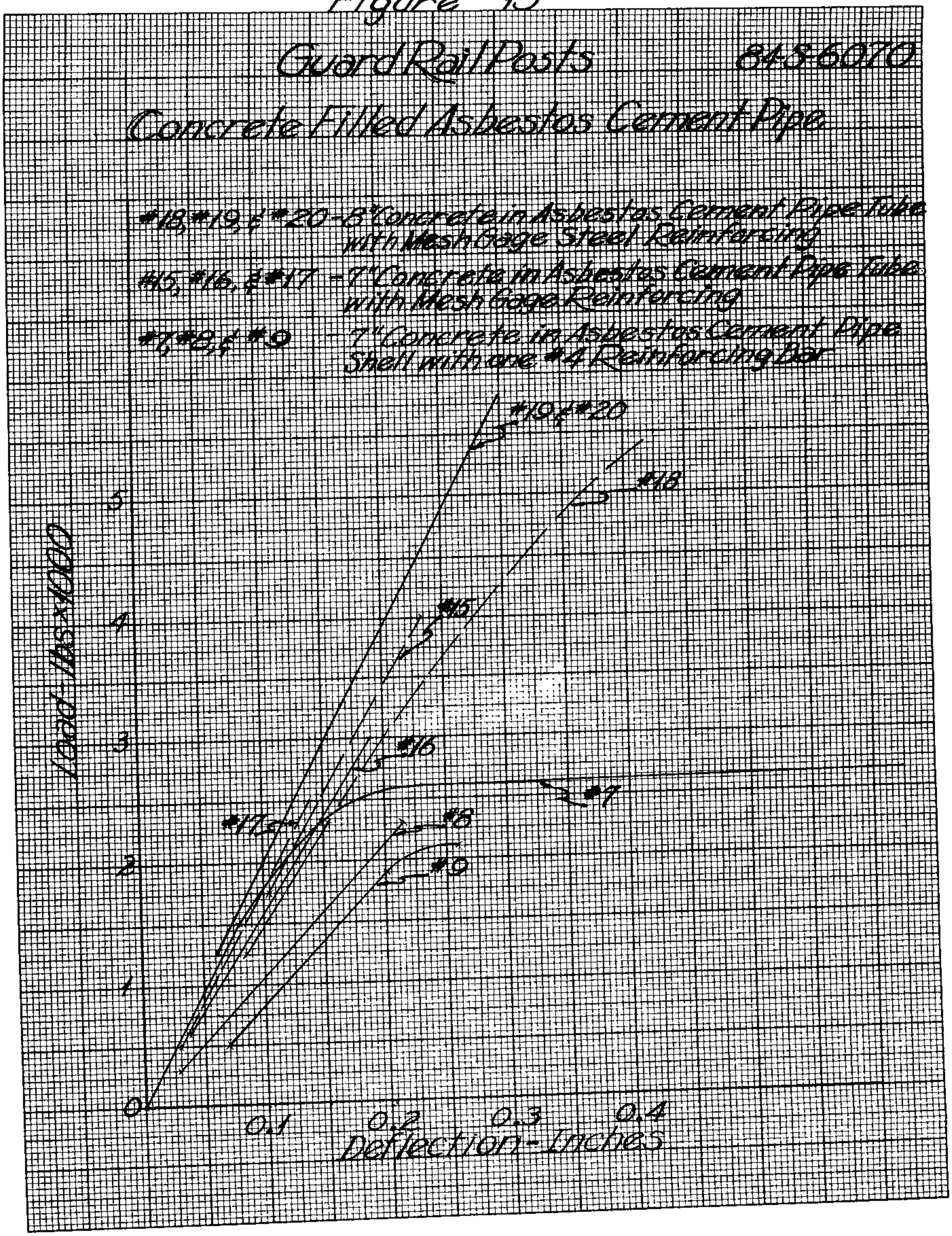
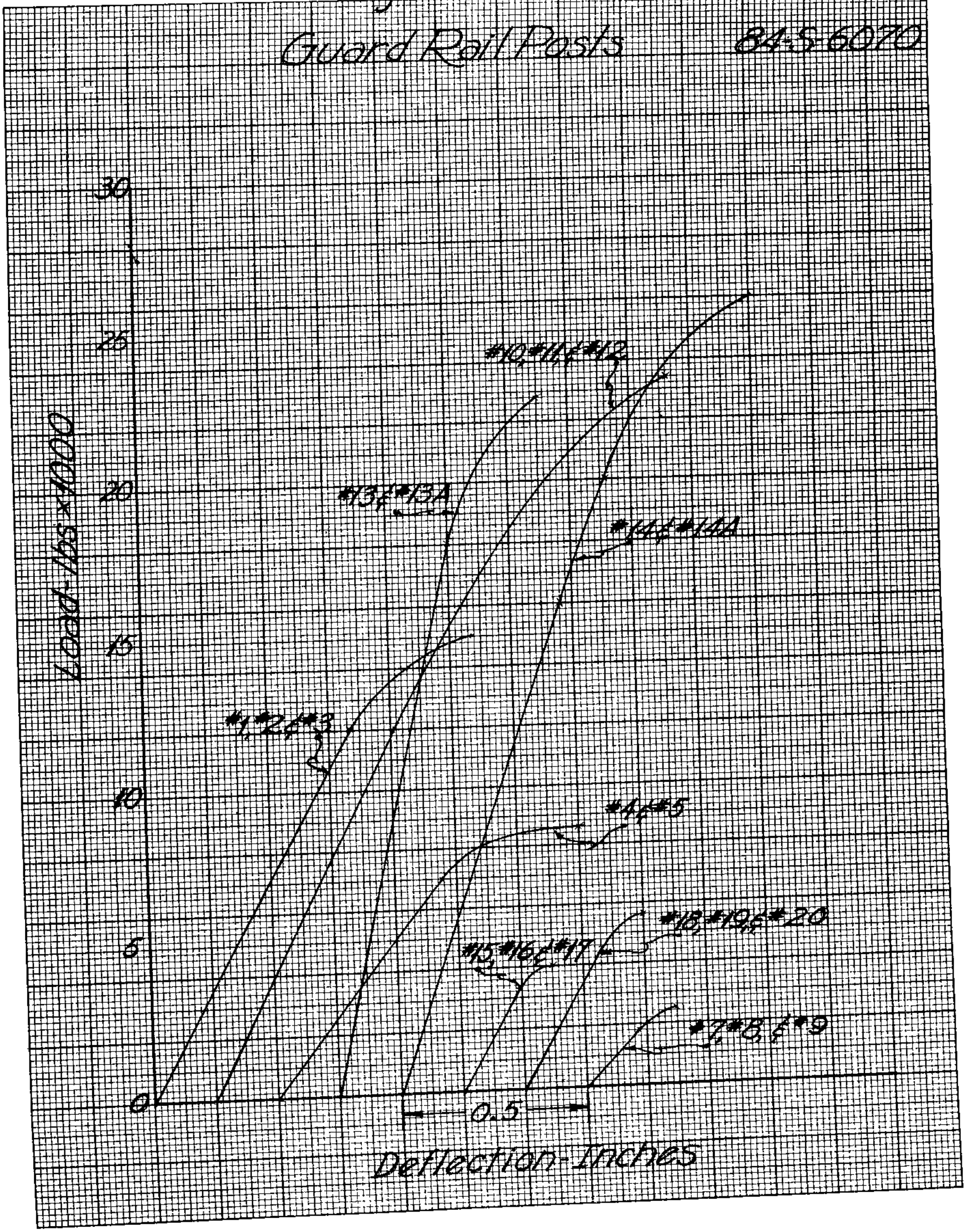

Guard Rail Posts
8456070
Concrete Filled Asbestos Cement Pipe
#18, #19, & #20 - 8" Concrete in Asbestos Cement Pipe Tube with Mesh Gage Steel Reinforcing
#15, #16, & #17 - 7" Concrete in Asbestos Cement Pipe Tube with Mesh Gage Reinforcing
#7, #8, & #9 - 7" Concrete in Asbestos Cement Pipe Shell with one #4 Reinforcing Bar
#19 & #20
#18
#15
#16
#7
#17
#8
#9
Load - lbs x 1000
0
1
2
3
4
5
0.1
0.2
0.3
0.4
Deflection - Inches

Figure # 14


Guard Rail Posts
84-S-6070
30
25
20
15
10
5
0
Load-lbs x 1000
#10,#11,&#12
#13,&#13A
#14&#14A
#1,#2,&#3
#4,&#5
#18,#19,&#20
#15,#16,&#17
#7,#8,&#9
0.5
Deflection-Inches

COMPARISON OF POSTS

Type	Approximate Cost, Installed	Comparative Struc. Strength (Cantilever Test)	Durability & Ease of Maint.
Treated Douglas Fir	$7.00	Good	Good
Redwood	7.00	Fair	Fair
H-beam	10.00	Good	Good
Split-beam	13.00	Poor	Good
Concrete	10.00*	Very Poor	Good, but no Salvage Value
Used Railroad Rail (60 lb.)	8.00	Good	Good

* Rough estimate by manufacturer

Above cost data are rough estimates based on limited data. Additional and more accurate data on these and other types will be furnished after completion of additional tests.